# Cosmology

## Prof. Roberto Auzzi

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The course aims to treat General Relativity and its applications to Cosmology.

At the end of the course, the student will know Einstein equation for the gravitational field and he will be able to apply general relativity to the study of the primordial universe and to black holes. The student will appreciate the relevance of the problem of the cosmological constant and of dark matter in modern cosmology. Moreover, he will know the basic of black hole thermodynamics.

***COURSE CONTENT***

Manifold, tensors in general relativity, covariant derivative

Riemann curvature tensor. Einstein equation and its Newtonian limit. A taste of linearized gravity and of gravitational waves.

Hypersurfaces. Stokes’s theorem.

Lagrangian formulation of Einstein equation. Cosmological constant.

Homogeneous and isotropic universe. Hubble’s law. Friedmann-Lemaitre-Robertson-Walker metric. Cosmological redshift. Friedmann equation.

Cosmological parameters. Introduction to Cosmic Microwave Background (CMB).

Lie derivative. Killing vectors.

Conformal transformations and Carter-Penrose diagrams. Killing horizons and surface gravity. Komar mass.

Rotating (Kerr) and charged (Reissner-Nordstrom) black holes. Penrose process and black hole thermodynamics.

***BIBLIOGRAPHY***

- S. Weinberg, *Gravitation and Cosmology* (Wiley, 1972).

- S.M. Carroll, *Spacetime and geometry: an introduction to general relativity (Addison-Wesley,* 2003).

- A. Zee, *Einstein gravity in a nutshell* (Princeton university press, 2013).

- B. Ryden, *Introduction to cosmology* (Cambridge university press, 2016).

- E. Poisson, *A relativist’s toolkit* (Cambridge university press, 2004).

***TEACHING METHOD***

Lectures in classroom.

***ASSESSMENT METHOD AND CRITERIA***

Oral examination. The oral exam intends to evaluate the assimilation of the concepts presented during the course, and will focus on the candidate's discussion and presentation of some points of the program. The evaluation of the oral test will take into account the correctness of the answers, their logical and methodological rigor, and the effectiveness of the presentation.

***NOTES AND PREREQUISITES***

The student must have some basic knowledge of special relativity and be familiar with the geodesic equation (it is recommended to have followed the Relativity course first).

Covid-19

In case the current Covid-19 health emergency does not allow frontal teaching, remote teaching will be carried out following procedures that will be promptly notified to students.

Prof. Roberto Auzzi receives in the office after the lessons.